

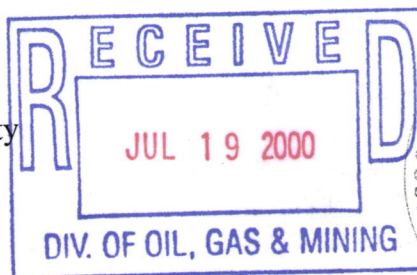
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Paula H. Doughty
Manager, Environmental Compliance

June 28, 2000

Kennecott

Mr. Don Ostler, Director
Division of Water Quality
Department of Environmental Quality
288 North 1460 West
P.O. Box 144870
Salt Lake City, Utah 84114-4870



Dear Mr. Ostler:

Subject: **Renewal Application - Ground Water Discharge Permit UGW350001;**
Kennecott Tailings Impoundment

Kennecott Utah Copper Corporation (Kennecott) hereby submits an application for renewal of the Tailings Impoundment Ground Water Discharge Permit UGW350001. This application includes updated versions of the following documents:

- Statement of Basis
- Appendix A- *Assessment of Acidification Potential*
- Appendix B - *Compliance and Operational Monitoring Plan*
- Standard Operating Procedure #1 - *The Complete Modified Sobek Acid Base Accounting*
- Standard Operating Procedure #4 - *Kinetic Net Acid Generation (NAG) Test.*

No changes to Standard Operating Procedures #2 and #3 are necessary, therefore they are not included in this submittal.

Notable changes to the Tailings Ground Water Discharge Permit UGW350001 sampling program include the following:

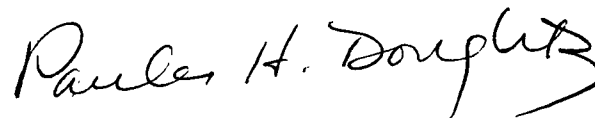
- 1) The acid/base accounting (ABA) sampling detailed in Appendix A has been modified to address the sampling frequency changes requested in the UDWQ letter dated March 1, 2000. The revised Appendix A frequencies are the same as those requested in the letter with the exception that semi-annual sampling is proposed for the Magna tailings and no sampling of the Hydromet and Slag Tailings is proposed following relocation of these flows to the West Cyclone Station. Both of these materials currently combine with Copperton tailings upstream of the Magna

Impoundment single point discharge prior to entering the impoundment. In the future the Hydromet and Slag Tailings will be directed to the West Cyclone Station where they will be combined with Copperton Tailings, North Concentrator tailings and Power Plant fly ash prior to discharge to the impoundment. The ABA characteristics of these materials will thus be monitored by the quarterly sampling of the cyclone underflow tailings and the semi-annual sampling of the overflow tailings. Sampling of the mixed and cycloned materials will give results that are more representative of materials actually being deposited on the impoundment than sampling of the individual streams.

- 2) The humidity cell kinetic test has been replaced with the Net Acid Generation (NAG) kinetic test. The reaction kinetics of the humidity cell tests have been shown to be very slow, resulting in no tailings samples having ever acidified. Even samples that were determined to be strongly acid generating by ABA analyses remained at a neutral pH in the humidity cells. Kennecott believes that the humidity cell tests are of little value for prediction of acid rock drainage and recommends the NAG test. The NAG test uses hydrogen peroxide to speed the oxidation reactions that occur under surface weathering conditions and will thus yield useful results within 24 hours.
- 3) The HNO_3 leach has been removed from the acid/base accounting analytical protocol. The HNO_3 leach was designed to identify organic sulfur in the tailings, but the tailings do not contain any significant concentrations of organic matter. (It should be noted that the removal of the HNO_3 leach will conservatively tend to increase the estimated acid potential of the samples by approximately five percent.)
- 4) The Appendix B semi-annual sampling schedule of Copperton tailings, North Concentrator tailings, Power Plant fly ash, Slag tailings and Hydromet tailings have been replaced with semi-annual sampling of the underflow and overflow tailings from the East and West Cyclone Stations following relocation of those flows to the West Cyclone Station. All of these streams will be discharged to the Cyclone Stations by the end of the year. Sampling of the mixed and cycloned materials will give results that are more representative of materials being discharged onto the impoundment than sampling of the individual streams. The samples will continue to be analyzed for total metals and SPLP.
- 5) The protection and compliance limits identified in Appendix B have been recalculated based upon additional five (5) years worth of monitoring data. Although similar to the compliance limits identified in the previous permit, some levels have drifted slightly upwards and others slightly downwards.
- 6) Both paste pH and paste conductivity analyses will be performed on tailings samples collected from the North Expansion Impoundment during the annual inspection. Field work conducted at the Bingham Canyon Mine has shown that paste conductivity analysis can identify sulfide oxidation products in the soil even if the soil has not yet acidified. Paste conductivity can also be used to identify highly saline soils that will not be able to support a healthy vegetation cover.

Should you have any questions regarding this permit renewal application and associated attachments, please don't hesitate to contact me at 252-3257.

Sincerely,

A handwritten signature in black ink, reading "Paula H. Doughty". The signature is fluid and cursive, with a large, stylized "P" and "D".

Paula H. Doughty
Manager, Environmental Compliance

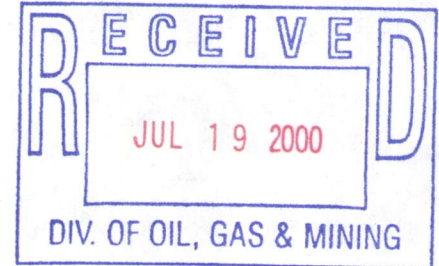
Attachment

cc: Ed Hickey, UDWQ

m/35/015

APPENDIX A

ASSESSMENT OF ACIDIFICATION POTENTIAL KENNECOTT TAILINGS IMPOUNDMENT (Revised June 21, 2000)



1.0 MONITORING OBJECTIVES

The objectives of this monitoring plan are as follows:

1. To characterize any potential water quality impacts resulting from potential future acidification of tailings material.
2. To accurately quantify the acidification potential that will occur on the impoundment.
3. To present an adequate characterization of acidification potential for the different units of both the existing and expansion portion of the Tailings Impoundment.

2.0 MONITORING PLAN

2.1 Acidification Monitoring

The primary objective of this portion of the monitoring program is to determine the acidification potential of both the existing and expansion portions of the tailings impoundment, using acid/base accounting (ABA) and Net Acid Generation (NAG) testing.

2.1.1 Sampling Locations

The Tailings North Expansion embankment is constructed of coarse underflow material from two cyclone stations (designated East and West Cyclones). The fine-grained overflow material is placed in the interior of the impoundment. The East Cyclone station currently receives material only from the Copperton Concentrator. The West Cyclone Station currently receives Copperton tailings, North Concentrator tailings, and Power Plant fly ash. Modifications to the piping system will allow for the West Cyclone to receive the inputs of Smelter slag and hydrometallurgical tailings which currently enter the Magna impoundment through the single point discharge point after being combined with Copperton tailings. In the future, Smelter process waters may be directed to the West Cyclone station as well. Whole tailings will continue to be discharged to enhance dust control activities. Through completion of reclamation activities on the Magna impoundment (i.e. year 2004). The discharge to the Magna impoundment is generally composed of

Copperton tailings, but sometimes may contain excess material from the West Cyclone Station.

Both slag tailings and the power plant ash contain abundant neutralizing capacity and little or no sulfide minerals, so there is little to no risk of acid generation from these materials. Hydrometallurgical tailings by the end of 2000 will be discharged to the West Cyclone Station and comprise <.5% of the flow entering the impoundment from the West Cyclone Station. The West Cyclone Station material will be characterized after mixing with the other tailings streams in the overflow and underflow samples. A sample will continue to be collected from the single point discharge until the Hydromet slag tailings are relocated to the West Cyclone Station.

The exterior of the existing impoundment has been adequately characterized by previous sampling efforts. Sampling locations to characterize the new impoundment and the interior of the existing impoundment include the following sites, to be sampled at the frequencies indicated in section 2.1.2.

- I. Interior of the Magna Impoundment
 - a. Copperton Concentrator Tailings
 - b. North Concentrator Tailings
 - c. Final Impoundment Lift
 - d. Single Point Discharge – (Until Hydromet and slag tailings are diverted to the West Cyclone Station)
- II. Embankment of the North Expansion cycloned tailings underflow)
- III. Interior of North Expansion (cycloned tailings overflow)

2.1.2 Sampling and Analysis for ABA Values

Samples will routinely be collected from a depth interval of 0 to 12 inches for tailings that are in place. However, additional samples may be taken from other depths for evaluation of areas of incipient acidification.

SOP #3 describes the standard protocol for sampling, preservation, chain of custody and archiving of samples. All samples will be archived for at least two years. The locations of the samples from the existing impoundment will be marked in the field with a stake and will be indicated on a reference map.

2.1.2.1 Interior of the Existing Impoundment

- A. Copperton Tailings – A quarterly grab sample will be collected from this tailings stream for a period of two years for ABA characteristics. After a period of two years (second quarter of 2002), sampling frequency may be reduced to semi-annually.

- B. Magna Concentrator Tailings – A semi-annual grab sample will be collected from this tailings stream. The Magna tailings are sampled less frequently than Copperton tailings because they only represent about 20 percent of the total tailings discharged to the impoundment, and they are all sent to the West Cyclone Station, where they are characterized by the quarterly sampling of the West Cyclone underflow and overflow material.
- C. Interior of Existing Impoundment – Twelve additional samples will be collected from the top surface of the central area of the existing impoundment after the final lift has been placed. The total of 12 is based on one or two samples from each of the reclaim areas that will be constructed post-closure. The samples will be distributed between the margins and the central area along the reclaim dikes as they are constructed between 1996 and 2004. For the larger areas, one sample will be taken near the margins and one near the center to evaluate possible horizontal variability. As samples are collected and analyzed KUC will analyze the data statistically to determine if the sample ABA mean identifies the population mean plus or minus 10 tons per 1000 tons at a 95% confidence interval. If the ABA samples do not characterize the population mean within the specified limits, KUC shall provide for approval by DOGM and UDWQ, either plans for additional sampling or justification why further sampling is not necessary.

2.1.2.2 Underflow Material in New North Embankment

Grab samples of underflow tailings will be collected quarterly from each cyclone station (two samples per quarter). The samples will be collected as the underflow is discharged from the cyclone.

2.1.2.3 Overflow Material in the North Expansion Impoundment

Grab samples of overflow tailings will be collected semi-annually from each cyclone station (two samples per quarter). The samples will be collected as the overflow material is discharged from the cyclone.

2.1.3 Testing Methods and Parameters

Samples of tailings solids will be analyzed using methods described in detail in the attached Standard Operating Procedures listed in section 4.0 (SOP's 1, 2, 3 and 4).

2.1.3.1 Static Testing

Samples of tailings solids will be analyzed for acid/base accounting using the protocol for ABA potential in SOP #1.

2.1.3.2 Kinetic Testing

The humidity cell kinetic testing protocol is listed in SOP #2. Routine humidity cell testing has been discontinued but the SOP has been retained in case the test is used on a discretionary basis in the future. The humidity cell test results are of limited usefulness because the kinetics of the sulfide oxidation and acid/base reactions in the test cells are very slow, and no tailings materials ever acidified (even those tested for over a year.) The test results could not be used to predict if a tailings sample would generate acid rock drainage in the future. To overcome this problem, kinetic Net Acid Generation (NAG) testing has been substituted for the humidity cells.

The protocol for the NAG test is listed in SOP #4. The kinetic NAG test involves the addition of a strong oxidizing agent, hydrogen peroxide, to the tailings sample. The hydrogen peroxide oxidizes the available sulfide in the sample at a rapid rate, mimicking years or decades of surface weathering in a matter of hours.

A minimum of fifteen kinetic NAG tests will be completed in the first year. The tests will be run on samples that have been analyzed by acid/base accounting techniques (SOP #1). The samples will be selected to provide a data set with a broad range of ABA potentials and neutralization potential ratios. At the end of one year the data will be analyzed to determine if the test is yielding useful results, and if the test should be continued as originally designed, modified, discontinued or replaced. If the test is continued after one year in its original or modified form, the testing will be conducted at a rate of six samples per year.

2.1.4 Quality Assurance

Replicate Samples: Split replicate samples will be included to evaluate the precision of the analyses. At least one replicate sample will be analyzed for every 20 samples (5%). Results will be acceptable if the Relative Percent Differences (RPD) of the ABA values differ by less than 35%.

Reference Samples: A large quantity of Kennecott underflow tailings sample has been collected, dried, homogenized, and archived as a reference material. The reference sample is a composite sample of tailings underflow material that has been thoroughly mixed and split into individual samples. (This is the same material as was used in the previous evaluation of the acidification potential of the tailings). Samples of the reference tailings material will be submitted to the analytical laboratory, together with the unknown samples, to determine the precision and consistency of the laboratory analyses. One reference sample will be submitted per 20 unknown samples. The results will be compared to those obtained for the same reference material in the previous evaluation of potential acidification (Shepherd Miller, Inc. and Schafer and Associates, 1995). If the RPD is within ± 1.5 standard deviations about the mean relative to past results for the same reference materials, the results will be accepted.

2.1.5 Inspection of Tailings North Expansion Embankment

Annual inspection of the North Embankment will be conducted to visually identify potential "hot-spots." If acidification appears to be developing based upon changes in color or lack of vegetation, the approximate outlines of the site will be marked on a map and a sample collected for soil paste pH and paste conductivity.

2.2 Operational Monitoring

The operational monitoring will be conducted as outlined in Kennecott's Operational Monitoring Plan (see Appendix B)

3.0 REPORTING

An annual report will be submitted by March 31 addressing the previous years monitoring as described in this plan and Appendix B.

The report will include:

- summary tables of the results of the ABA analyses and the analyses of the final kinetic NAG test leachate,
- graphs showing the pH and temperature variation during the kinetic NAG tests,
- a comparison of the past year's geochemical data with the preceding years,
- a comparison between the ABA and kinetic test results (In particular, at what ABA potential and neutralization potential ratio the tailings will acidify),
- a summary of the results of the North Embankment inspection including a map of any areas that have acidified.

- a summary of all surface water, seep, lysimeter and groundwater data collected in accordance with Appendix B.

4.0 STANDARD OPERATING PROCEDURES (SOP's)

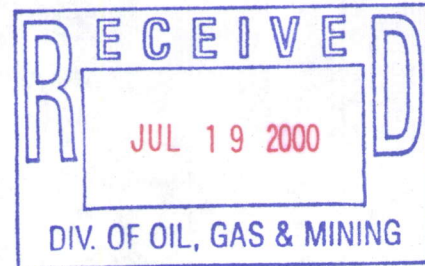
The following SOP's are attached to this plan:

1. Standard Operating Procedure #1 – The Complete Modified Sobek Acid Base Accounting.
2. Standard Operating Procedure #2 – Kinetic Testing by the Humidity Cell Procedure.
3. Standard Operating Procedure #3 – Sample Collection, Preservation, Chain of Custody, Archiving, and Quality Assurance.
4. Standard Operating Procedure #4 – Kinetic Testing by the Net Acid Generation (NAG) Procedure.

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STANDARD OPERATING PROCEDURE #1

The Complete Modified Sobek Acid Base Accounting



Groundwater Discharge Permit No. UGW350011

Appendix A

Revision 6 - June 2000

Prepared by: Kennecott Utah Copper

I. TITLE

THE COMPLETE MODIFIED SOBEK - ACID BASE ACCOUNTING

II. SUMMARY

The purpose of this procedure is to measure the acid generating and neutralization potential of waste rock and tailings. This procedure is based on an original procedure developed by A. A. Sobek and others (1978 - EPA Method 600/2-78-054). Several modifications were made to this original method as recommended by Lawrence and others (1989) and White and Others (1996). Other minor modifications were also made to facilitate equipment present at the Kennecott Laboratory.

The acid generating potential results from the presence of metallic sulfide minerals. The sulfides contained in these minerals may be converted to sulfuric acid by oxidation of the sulfur. If sufficient neutralizing capacity is not present, the material may become acidic. This method measures the total concentration of sulfur, differentiates the forms of sulfur present, and measures the neutralization potential. The total sulfur present is determined analytically using a LECO Furnace. The forms of sulfur present are determined by leaching the samples with water, hydrochloric acid, and nitric acid and then analyzing the leached samples for sulfur using the LECO Furnace.

This method is based on the assumption that the forms of sulfur present in the sample can be differentiated as follows:

- Gypsum and some other sulfate minerals, are soluble in a hot water leach.
- Most sulfate minerals and other non-acid producing forms of sulfur are removed by a HCl leach.
- Sulfate, non-acid producing forms, and sulfide forms of sulfur, such as pyrite are removed during the HNO₃ acid leach.
- Forms of sulfur remaining after the HNO₃ leach (residual sulfur) will be primarily non-acid forming organic sulfur compounds.

Then, by subtraction, the various forms of sulfur can be evaluated. The portion of the sample comprised of iron-bearing sulfidic forms of sulfur (predominantly pyrite, chalcopyrite and bornite at Bingham Canyon) is of primary interest since it is this form that produces acid. The concentration of acid-forming sulfide sulfur in the sample is determined by subtracting the HCl extractable forms of sulfur from the concentration of total sulfur present in the sample. The hot water leach is optional since sulfate forms are extracted by both the hot

water and HCl leach. The HNO₃ leach is also optional because the tailings and waste rock do not contain significant quantities of organic sulfur. It should be noted that the exclusion of the HNO₃ leaching results will conservatively tend to overestimate the sulfide sulfur in the sample.

The Neutralization Potential (NP) is measured by over-acidifying the sample and then measuring the excess acid and determining the amount of acid consumed by the sample. The net neutralizing capacity of the sample is reported as the Acid Base Account (ABA) of the sample, which is the difference between the NP and the Acid Potential (AP) as determined from the concentration of pyritic sulfur. Total sulfur and the forms of sulfur are reported as percent sulfur, while the NP, AP and the ABA are reported as tons CaCO₃/1000 tons.

III. PROCEDURES

Each sample for ABA analysis will follow all of the following procedures.

A. Sample Preparation

1. Apparatus:

- a) Drying Oven
- b) Mesh screen

- (1) All samples will be oven dried at 80°C¹ and homogenized by the laboratory prior to the start of any analytical procedures. All ABA analyses will be run on a portion of sample ground to less than or equal to 200 mesh. Approximately 5 grams of material will be required.

B. Total Sulfur

1. Reagents and Apparatus:

- a) Leco Sulfur Analyzer

¹ Recommended in ASTM D 5744 9.4

- b) Balance with 0.0001g readability
- c) Leco Crucible

2. Procedure

- a) Weigh suitable sample aliquot of (0.1-1.0g) into a Leco crucible.
- b) Analyze the sample on the Leco CNS2000 Analyzer following the manufacturer's specifications.

3. Reporting:

- a) The result from this procedure is the Percent **Total Sulfur**.

C. H2O Extractable Sulfur (If requested)

1. Reagents and Apparatus:

- a) Filter rack and glass Funnels.
- b) S&S 589 white ribbon filter paper or equivalent.
- c) ASTM Type II Reagent water.
- d) ml beaker to boil water.
- e) Microwave to boil the container of water.
- f) Balance with 0.001g readability.

2. Procedure:

- a) Weigh a 1-2g sample.
- b) Fold white ribbon filter paper and place inside the glass funnels.
- c) Transfer soil sample to the filter paper.

- d) Slowly add a total of 100 ml in two or more increments of the boiling water to the sample. Be careful not to lose any sample by run over, splashing or breaking through the filter paper.
 - e) Allow the sample to air dry overnight.
 - f) The soil sample is analyzed on the Leco Sulfur Analyzer following the manufactures specifications for sulfur.
3. Reporting:
- a) H₂O Extractable Sulfur is reported in percent using:
Total Sulfur – Sulfur remaining in the H₂O-leached sample.

D. HCl Extractable Sulfur

1. Reagents and Apparatus:

- a) Filter rack and glass Funnels.
- b) S&S 589 white ribbon filter paper or equivalent.
- c) Reagent grade HCl/ASTM Type II Reagent water.
- d) Balance with 0.001g readability.
- e) AgNO₃ - 10g into 90 ml of ASTM Type II water bring to 100 ml volume. Keep reagent in an amber bottle.

2. Procedure:

- a) Weigh a 1-2g sample.
- b) Fold white ribbon filter paper and place inside the glass funnels.
- c) Transfer soil sample to the filter paper.

- d) Slowly add a total of 100 ml in two or more increments of the 2:3 HCl reagent to the sample. Be careful not to lose any sample by run over, splashing or breaking through the filter paper.
- e) Rinse sample with deionized H₂O until all traces of Cl⁻ ions are removed. Verify the Cl ion by testing filtrate with 3 drops of AgNO₃ to see if a precipitate forms. If a precipitate forms continue washing the sample with deionized water. If no precipitate forms continue with the procedure.
- f) Allow the sample to air dry overnight.
- g) Remove the soil from the filter paper and place in a tarred solo plastic cup. Record the weight of the sample.
- h) The soil sample is analyzed on the Leco Sulfur Analyzer following the manufactures specifications for sulfur.
- i) Weight Correction:
 - (1) This procedure is done to correct for weight loss due to dissolution during leaching the sample, since the Leco sulfur apparatus reports percent sulfur on the actual weight of the leached sample used for the determination
 - (2) Correction for the amount of sample dissolved is accomplished as in the following example:

% Sulfur Corrected = % Sulfur Uncorrected times
(1-(Initial weight-final weight)/initial weight).
Example:

Sample Weight before washing = 2.3211
Sample Weight after washing = 1.6922
Difference = 0.6289

$$0.6289/2.3211=0.27$$

Sulfur = 2.78

Then $2.78(1-0.27) = 2.03$

3. Reporting:

- a) Report (Total Sulfur-Weight corrected Sulfur in the extracted sample) as HCl Extractable %.

E. HNO₃ Extractable Sulfur (if requested)

1. Reagents and Apparatus:

- a) Balance with 0.001g readability
- b) Hot plate.
- c) Beakers.
- d) Reagent grade HNO₃/H₂O
- e) Type II Reagent Water

2. Procedure:

- a) Weigh a soil sample of 1-2g of less than or equal to 200 mesh into a 150 ml beaker.
- b) Add 50 ml of 1:7 HNO₃/H₂O.
- c) Place sample on hot plate. Heat to near boiling cover and Continue to digest for six hours. (Do not allow sample to become dry.)
- d) Let samples cool.
- e) Filter the sample and rinse thoroughly to remove all traces of NO(approximately 200 ml of H₂O).

- f) Allow the samples to air dry.
- g) Remove the soil from the filter paper and place in a tarred solo plastic cup. Record the weight of the sample.
- h) Carefully transfer the sample to a Leco crucible.
- i) Analyze the sample on the Leco Automatic Sulfur Analyzer following the manufactures specification for sulfur.
- j) Weight Correction:
 - (1) This procedure is done to correct for weight loss due to dissolution during leaching the sample, since the Leco sulfur apparatus reports percent sulfur on the actual weight of the leached sample used for the determination.
 - (2) Correction for the amount of sample dissolved is accomplished as in the following example:

$$\% \text{ Sulfur Corrected} = \% \text{ Sulfur Uncorrected times} \\ (1 - (\text{Initial weight} - \text{final weight}) / \text{initial weight}).$$

Example:

Sample Weight before washing = 2.3211
Sample Weight after washing = 1.6922
Difference = 0.6289

0.27

Sulfur = 2.78

Then $2.78(1 - 0.27) = 2.03$

3. Reporting:

- a) Report as (Total Sulfur-Weight corrected Sulfur in the leached sample)
as % HNO3 Extractable.

F. **Residual Sulfur (if requested)**

1. Residual Sulfur is calculated as follows:

$$\text{Residual Sulfur} = \text{Total Sulfur} - (\text{HCl Extractable} + \text{HNO}_3 \text{ Extractable Sulfur})$$

G. **Calculation of Acid Potential as Tons CaCO₃/1000 tons soil.**

1. Calculation:

$$\text{Acid Potential} = \text{Total sulfur} - \text{HCL extractable Sulfur} * 31.25$$

- is a factor which yields the Acid Potential in terms of tons CaCO₃/1000 tons soil.

H. **Neutralization Potential - Lime as CaCO₃**

1. Summary

The neutralization potential is to determine the neutralizing bases, including the carbonates, present in a given sample. A known volume of HCl is added to the sample. The sample is heated to ensure that the reaction goes to completion. The CaCO₃ equivalent of the sample is obtained by determining the amount of unconsumed acid by titration with standardized sodium hydroxide.

2. Apparatus:

- 100 ml beakers
- Mettler DL 70 Autotitrator equipped with ST20 Autosampler
- pH meter

3. Reagents:

- a) 1:3 HCl/H₂O
- b) 0.1 N HCl certified.
- c) 0.5 N HCl certified.
- d) 0.25 N NaOH certified.
- e) Potassium Acid Phthalate primary standard grade.

4. Standardizing Reagents:

- a) Standardize the NaOH solution by weighing 1.00g Potassium acid phthalate into three disposable beakers. Write down the exact weight and enter into the titrator program when requested. Titrate with certified 0.25 NaOH to the break point using the DL70 autotitrator and DL70 routine CAL1. The routine will add sufficient DI water, titrate to the dynamic² end point, and calculate the NaOH normality automatically.
- (1) Verify the standardization of the Hydrochloric Acid solution by placing three 10 ml aliquots of the HCl solution into a plastic disposable beaker. Titrate to the end point using routine CAL 3. The method calculates the HCL normality automatically.

5. Procedure:

² The dynamic endpoint is that part of the titration curve where the slope is at a maximum. It has been found that when particulates are present in the sample, this means of end point determination yields results that are much more reproducible and accurate than a preset endpoint. Unfortunately this requires the use of an autotitrator with this capability.

- a) In lieu of determining the fizz rate, place a 1.0g sample in an Erlenmeyer flask. (If the sample is low in neutralization potential then 0.1N HCl should be used.)
- b) Add 10 ml of 0.50/0.10 N HCL slowly to the sample.
- c) Add 75 ml of deionized water and reflux for 1 minute to drive off CO₂. The reaction is complete when no gas evolution is visible and particles settle evenly over the bottom of the flask . Let cool.
- d) Calibrate the pH meter according to the pH manual.
- e) Set cooled sample on the stir plate with the stir bar in the sample. Insert the pH probe, keeping the stir bar from hitting the probe.
- f) The pH of the solution should read less than 2.0³ If the pH is less than 2.0, proceed with the titration step. If the pH is greater that 2.0 repeat the above steps using half the amount of sample used. A reagent blank is required.
- g) After transferring the sample to a 100 ml titration beaker, titrate the sample using the 0.25 N NaOH to the end point using routine KA05 for 0.5 N HCl or KA04 for 0.1N HCl.

(1) REAGENTS & APPARATUS

- (a) Mettler DL70 ES Titrator with auto sampler tray, automatic stirrer and a 20 ml Burette with 0.01 ml precision in delivery.
- (b) Calibrated Mettler auto titrator cups. (Cups are calibrated from 20 ml to 100 ml with 20 ml increments.)
- (c) Standard Sodium Hydroxide 0.25N spike solution
Fisher Scientific Certified Standard.

³ See White, W.W. III; Cox, R. L.; Lapakko, K. A. *STATIC-TEST METHODS MOST COMMONLY USED TO PREDICT ANCID MINE DRAINAGE: Practical Guidelines for Use and interpretation* p. 13

(2) PROCEDURE

- (a) Calibration:
 - (i) Titrant verification: (This is done when a new lot of Titrant is received. See section 4.)
- (b) Daily pH electrode Calibration:
 - (i) Obtain pH Buffer solutions pH 4, pH 7, pH 10.
 - (ii) Pour into the titrator cup approximately 60 mls.
 - (iii) Place sample cups in the auto sampler.
 - (iv) Select Analysis from Main Menu.
 - (v) Add routine (Press Run.)
 - (vi) Type KC01 (Press run twice)
 - (vii) Type in identity of buffers and press run after each buffer.
 - (viii) The titrator will then advance the sample tray and perform the calibration of the electrode.
- (c) Sample Preparation
- (d) Using the 100 ml calibrated Mettler Titrate Cups write the Lab # on the cup and pour prepared samples into the titration beakers.
- (e) Place samples in the autosampler tray. (Remember to count the number in the run including the QC samples.)

- (f) For QC samples: Write the Lab # on the cups and use the "chosen" QC sample to prepare and pour the original, duplicate, spike 1, spike 2, blank and blank spike. (A 50 mg addition of Calcium Carbonate is made to all spike samples prior to digestion.)
- (g) After the Daily Calibration is done running, return to the method screen.
- (h) Add routine (hit run)
- (i) Type KA05/KA04 and enter the number of samples in the batch and press run. The next screen is for typing in the sample id. After completing the sample ID table press run twice and the Titrator will start. (If you have more than twenty samples then you must empty the determined samples out of the autosampler and add the remaining samples. The maximum number of samples is 32.) The titrator will then proceed to sequentially determine each sample using the dynamic endpoint. (The titrator is restrained to have a pH of 7.)
- (j) Run reagent blanks by titrating the appropriate volumes of HCl with 0.25N NaOH.

(3) Calculations:

- (a) Neutralization Potential (NP) in tons is calculated by the method using the equation below:

$$\text{Tons Ca CO}_3/\text{Kton} = \frac{(\text{Volume acid} \times \text{Normality of acid} - \text{Volume base} \times \text{Normality of base}) * 50}{\text{Sample Weight}}$$

I. Calculation of Acid/Base Accounting Potential as Tons CaCO₃/1000 tons

1. Calculation

$$\text{ABA Potential} = \text{Neutralization Potential} - \text{Acid Potential}$$

IV. QUALITY CONTROL

- A. All sample runs will include a Known Control, a Duplicate, a Blank, and a Spiked Blank for at least every 20 samples.
- B. Duplicates must achieve an RPD of less than 35%, or the sample set must be reanalyzed.
- C. Known Control samples must be within statistical control limits as determined using the Shewhart control limits.
- D. Spiked Blanks must recover 80-120 % of true value

V. REFERENCES:

- A. EPA- 600/2-78-054. Field and Laboratory methods Applicable to Overburden and Minesoils. Industrial Environmental Research Laboratory, Office of Research and Development, U.S. EPA, Cincinnati.
- B. EPA-670/2-74-070. Mine Spoil Potentials for Soil and Water Quality. Nation Environmental Research Center, Office of Research and Development, U.S. EPA, Cincinnati.
- C. A.S.T.M. D744 Standard Method for Accelerated Weathering of Solid Materials Using Modified Humidity Cell.
- D. Society for Mining, Metallurgy, and Exploration, Inc. Prediction of the Behavior of Mining and Processing Wastes in the Environment. Richard W. Lawrence, 1990 Pgs 115-121.
- E. Operating manual for the LECO Sulfur Furnace.
- F. Operating manual for the Mettler DL70 Autotitrator.

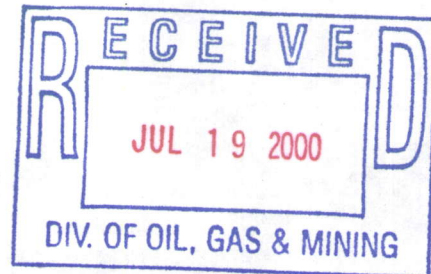
AMMENDMENT

(The reporting format is not typically placed in KEL SOPs. Therefore it will be listed as an amendment to the ABA SOP.)

The following analytes will be reported for Acid Base Accounting:

Total Sulfur
Hot water Extractable Sulfur (if requested)
HCl Extractable Sulfur
HNO3 Extractable Sulfur (if requested)
Residual Sulfur (if requested)
Acid Potential
Neutralization Potential
Acid/Base Accounting Potential

m/35/015



STANDARD OPERATING PROCEDURE #4

Kinetic Net Acid Generation (NAG) Test

Ground Water Discharge Permit No. UGW350011

Appendix A

June 2000

Prepared by: Kennecott Utah Copper



STANDARD OPERATING PROCEDURE FOR THE KINETIC NET ACID GENERATION (NAG) TEST

I. SUMMARY

The net acid generation (NAG) test is based on a hydrogen peroxide oxidation procedure developed by Finkelman and Giffen (1986) to determine the pyrite content of coal overburden.

The (NAG) test involves the addition of hydrogen peroxide (H_2O_2) to a sample of tailings or waste rock. The hydrogen peroxide causes rapid oxidation of the exposed sulfide minerals in the sample and the release of metals, sulfate and acidity.

The primary sulfide minerals in tailings and waste rock from the Bingham Canyon Mine are pyrite and chalcopyrite. Both of these sulfide minerals are readily oxidized during the NAG procedure. Pure samples of these minerals mixed with hydrogen peroxide will yield solutions with a pH of less than 3 and high acidity within 24 hours (Jennings et al, 2000).

The acidity may be neutralized in situ if calcium carbonate or other neutralizing minerals are present in the sample. The other sulfide oxidation products may be precipitated out as secondary minerals in the sample or may remain in solution. The NAG test thus accelerates the chemical reactions that may occur in tailings or waste rock over years or decades of weathering, and can predict if and when a material will generate acid rock drainage (ARD) in the long term. After the addition of hydrogen peroxide, the sample is allowed react for up to 24 hours. At the end of the test, the solution is filtered, heated and analyzed for pH, EC, sulfate, acidity, alkalinity and the trace metals Arsenic, Cadmium, Chromium, Copper, Lead, Selenium and Zinc.

As described by Schafer (2000) the NAG test provides information that is not available from static acid/base accounting (ABA) analyses alone. It is particularly useful in identifying samples that may acidify when the ABA potential is less than 10 or when the neutralization potential ratio is near one. The hydrogen peroxide will not react with sulfides that are enclosed by silicates or other inert minerals, or with sulfides that become armored with secondary minerals during the oxidation process. Similarly, the acid generated by sulfide oxidation will not be neutralized in situ by carbonate minerals unless they are exposed and unarmored. The NAG test results are thus only influenced by the available acid potential and available neutralization potential of a sample and so may be more indicative of material behavior under surface weathering conditions.

According to Miller (1997), the Kinetic NAG test provides the same data as a humidity cell. The time it takes for a sample to acidify and for the temperature to spike, is directly related to the time it would take to acidify the sample in a humidity cell. However, unlike humidity cells, the strongly oxidizing environment of the NAG tests insures that sulfide oxidation reactions will occur in 24 hours instead of months or years. This standard operating procedure is modified from protocols recently developed by Miller (1997).

II. PROCEDURES

1. Sample Preparation

1.A.1. Tailing samples will be homogenized before a representative split is taken.

No other preparation work will be required before analysis.

1.A.2. Rock samples will be crushed to a minus ten (-10) mesh before splitting.

The rock split will then be pulverized to -200 mesh prior to analysis.

2. NAG Testing

2.A.1. Reagents

2.A.1.a. 15% hydrogen peroxide (H₂O₂) solution.

2.A.1.a.1. 15% solution prepared by diluting 30 % H₂O₂ with DI water.

2.A.1.b. Adjust pH of H₂O₂ with dilute NaOH to a range of 4 – 7 if necessary.

2.B.1 Apparatus

2.B.1.a. 500 ml beakers

2.B.1.b. Watchglasses for 500 ml beakers

2.B.1.c. Analytical balance with a 0.001 gram readability.

2.B.1.d. Magnetic stirrer

2.B.1.e. Hot plate

2.B.1.f. Filtration apparatus

2.B.1.g. pH Meter with temperature probe.

2.B.1.h. Data Logger

2.B.1.i. Filtration apparatus.

2.C. NAG Procedure

2.C.1. Weigh 2.50 grams of sample into a 500 ml beaker.

2.C.2. Set up data logger and instrumentation to record the solution pH and temperature at a maximum of one-minute intervals for the first ten minutes of the test and at a maximum of five-minute intervals for the duration of the test.

2.C.3. Place the beaker on a magnetic stirrer.

2.C.4. Accurately measure 250 ml of room temperature 15% hydrogen peroxide solution into the beaker.

2.C.5. Begin recording the temperature and pH of the solution.

2.C.6. Cover with a watchglass and place in a fumehood or well-ventilated area. (Caution: the reaction can generate temperatures of up to 120 degrees C.)

2.C.7. Allow the sample to react for a minimum of two hours or until all effervescing ceases. (The test should not extend beyond 24 hours.)

2.C.8. Record the ending temperature and pH of the test.

2.C.9. Filter the sample using a glass fiber filter to remove suspended solids.

2.C.10 Transfer the solution to a new beaker and gently boil on a hot plate for a minimum of two hours and until effervescence stops (add deionized water if necessary, do not allow the sample to go dry).

- 2.C.11. Cool, and bring the solution volume back to 250 ml.
- 2.C.12. Record the final pH and conductivity (KEL SOP 3002.00 and 3005.00).
- 2.C.13. Report final pH as NAG pH and final conductivity as NAG conductivity

2.D. Acidity: From the NAG filtrate, a sample portion will be analyzed for Acidity using EPA Method 305.1

2.E. Alkalinity: From the NAG filtrate, a sample portion will be analyzed for Alkalinity using EPA Method 310.1

2.F. Sulfate: From the NAG filtrate, a sample portion will be analyzed for Sulfate (SO₄) using EPA Method 9036.

2.G. Metals: From the NAG filtrate, a portion of the sample will be analyzed by EPA Method 6010B for As, Cd, Cr, Cu, Pb, Se and Zn.

IV. CALCULATIONS

The NAG potential is reported as grams of H₂SO₄/kg. of sample and should be calculated as follows:

$$\text{NAG} = (49)\text{VM}/\text{W}$$

where: V = volume (ml) of NaOH titrated

M = molarity of NaOH (moles/l)

W = weight of sample reacted (g)

If the NAG potential exceeds 25 grams H₂SO₄/kg the test should be repeated using a 1.0 gram sample.

V. REPORTING

- A. The time, pH and temperature recorded during the NAG test will be provided in a spreadsheet format. This should include the ending pH, temperature and time.
- B. Final report will include:
 - NAG pH (standard units)
 - NAG Conductivity (umhos/cm)
 - Acidity (mg/L as CaCO₃),
 - Alkalinity (mg/L as CaCO₃)
 - Sulfate (mg/L)
 - Metals (mg/L).
- C. The calculations of the NAG potential should be reported as grams H₂SO₄/kg.

VI. REFERENCES

Finkelman, R.B. and D.E.Giffin, 1986. Hydrogen peroxide oxidation: an improved method for rapidly assessing acid-generating potential of sediments and sedimentary rocks. *Reclamation and Revegetation Research*, **5**, pp. 521-534.

Jennings, S., D.J. Dollhopf and W.P. Inskeep, 2000. Acid production from sulfide minerals using hydrogen peroxide weathering. *Applied Geochemistry* (in press).

Miller, S.D., A. Robertson, T. Donahue, 1997. Advances in acid drainage prediction using the net acid generation (NAG) test, *Proceedings of the 4th International Conference on Acid Rock Drainage*, Vancouver, British Columbia, pp. 533-549.

Sobek, W.M., 2000. Use of the net acid generation pH test for assessing risk of acid generation, *Proceedings of the 5th International Conference on Acid Rock Drainage*, Denver, Colorado, pp. 613-618.